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Batch: C

EXPERIMENT NO.1

Aim: To study different types of physical layer wired/wireless connections.

Theory:

Physical Layer[1]:

Physical layer is the lowest layer of the OSI reference model. It is responsible for sending bits from one computer to another. This layer is not concerned with the meaning of the bits and deals with the setup of physical connection to the network and with transmission and reception of signals.

Wired Networks:

A **wired network** is a common type of **wired** configuration. Most **wired networks** use Ethernet cables to transfer data between connected PCs. In a small **wired network**, a single router may be used to connect all the computers. Larger **networks** often involve multiple routers or switches that connect to each other.

1. **Fibre Optic Cable[2]:** Fibre optic technology converts electrical signals to light pulses (on/off) and sends the light pulses through transparent glass fibres about the diameter of a human hair. There is less signal loss or degradation with fibre optic technology than conventional copper wires or coaxial cables. Fibre transmits data at speeds far exceeding current DSL or cable modem speeds.

   1.1 Specifications:

Category	Description	Specifications	
		Before cabling	After cabling
Optical Specifications	Attenuation @1310 nm	≤0.34 dB/km	≤0.36 dB/km
	Attenuation @1550 nm	≤0.20 dB/km	≤0.22 dB/km
	Zero Dispersion Wavelength	1300~1324 nm	
	Zero Dispersion Slope	≤0.092 ps/nm^2·km	
	PMD (Polarization Mode Dispersion)	≤0.2 ps/√km	
	Cable Cutoff Wavelength (λ_{cc})	≤1260 nm	
	Macro bending Loss (100 turns; Φ50 mm) @1550 nm (100 turns; Φ50 mm) @1625 nm	 ≤ 0.05 dB ≤ 0.10 dB	
	Mode Field Diameter @1310 nm	9.2±0.4μm	
Dimensional Specifications	Cladding Diameter	125 ±1μm	
	Core/clad concentricity error	≤0.6μm	
	Cladding Non-Circularity	≤1.0%	
Mechanical Specifications	Proof stress	≥0.69Gpa	

1.2 Scalability[3]:

Fibre optics are much more **scalable** meaning that new equipment can easily be laid over the original **fibre**, with wavelengths turned on and off to allow for quick scaling if needed. Spare **fibre optics** can be included for future use and additional **cables** also laid at a later stage.

1.3 Schematic View:

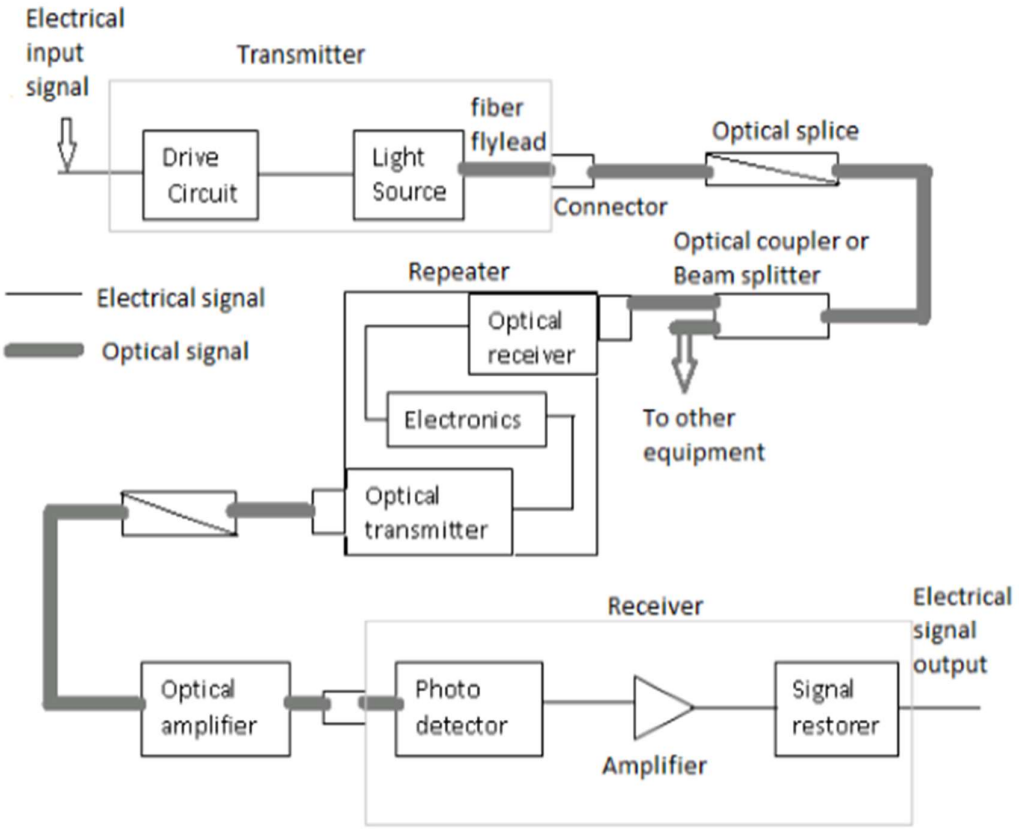


Figure 1

1.4 Modulation Scheme[4]:

Time Division Multiplexing is the technique used in fiber optic modulation, which combines the lower capacity channels into one high capacity channel.

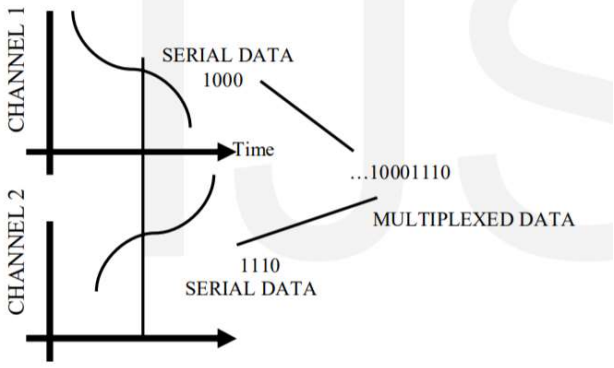


Figure 3 — Time-division Multiplexing (Source [14])

2. Ethernet[5]:

Ethernet is a way of connecting computers together in a local area network or LAN. It has been the most widely used method of linking

computers together in LANs since the 1990s. The basic idea of its design is that multiple computers have access to it and can send data at any time. This is comparatively easy to engineer.

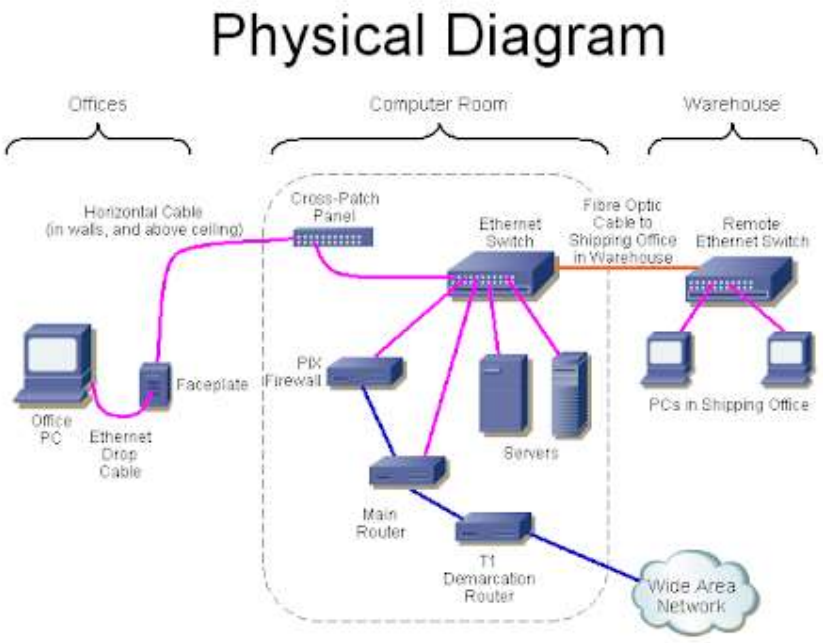
2.1 Specifications:

Name	IEEE Standard	Data Rate	Media Type	Maximum Distance
Ethernet	802.3	10 Mbps	10Base-T	100 meters
Fast Ethernet/ 100Base-T	802.3u	100 Mbps	100Base-TX 100Base-FX	100 meters 2000 meters
Gigabit Ethernet/ GigE	802.3z	1000 Mbps	1000Base-T 1000Base-SX 1000Base-LX	100 meters 275/550 meters 550/5000 meters
10 Gigabit Ethernet	IEEE 802.3ae	10 Gbps	10GBase-SR 10GBase-LX4 10GBase-LR/ER 10GBase-SW/LW/EW	300 meters 300m MMF/ 10km SMF 10km/40km 300m/10km/40km

2.2 Scalability[6]:

the **scalability of Ethernet** is limited by broadcast and control overhead, forwarding table state, and a lack of ability to perform traffic engineering. There are many proposed network designs that meet the criteria for replacing **Ethernet**.

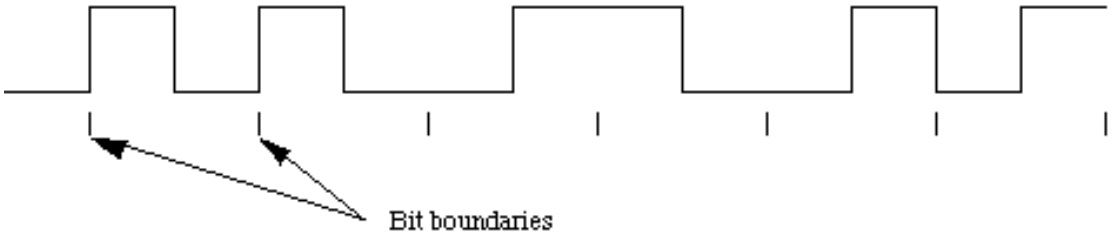
2.3 Schematic View:



2.4 Modulation Scheme[6]:

- Ethernet uses biphase modulation to transmit data bits. This is accomplished by using a Manchester encoded bit stream.
- Because Ethernet is not bandwidth limited by the FCC, Ethernet does not use IQ modulation.

Pulse shape



The waveform for a Manchester encoded bit stream carrying the sequence of bits 110100.

3. Twisted Pair Cable[7]:

The twisted-pair cable was primarily developed for computer networks. This cable is also known as **Ethernet cable**. Almost all modern LAN computer networks use this cable. This cable consists of color-coded pairs of insulated copper wires. Every two wires are twisted around each other to form pair. Usually, there are four pairs. Each pair has one solid color and one stripped color wire. Solid colors are blue, brown, green and orange. In stripped color, the solid color is mixed with the white color. Based on how pairs are stripped in the plastic sheath, there are two types of twisted-pair cable; UTP and STP.

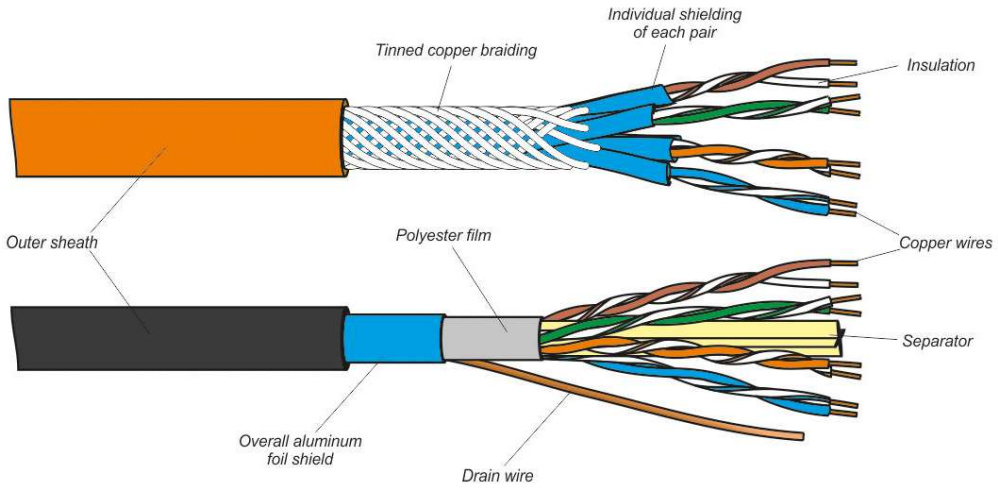
3.1 Specifications[8]:

Category / name of the cable	Maximum supported speed	Bandwidth/support signals rate	Ethernet standard	Description
Cat 1	1Mbps	1MHz	Not used for data	This cable contains only two pairs (4 wires). This cable was used in the telephone network for voice transmission.
Cat 2	4Mbps	10MHz	Token Ring	This cable and all further cables have a minimum of 8 wires (4 pairs). This cable was used in the token-ring network.
Cat 3	10Mbps	16MHz	10BASE-T Ethernet	This is the first Ethernet cable that was used in LAN networks.
Cat 4	20Mbps	20MHz	Token Ring	This cable was used in advanced Token-ring networks.
Cat 5	100Mbps	100MHz	100BASE-T Ethernet	This cable was used in advanced (fast) LAN networks.
Cat 5e	1000Mbps	100MHz	1000BASE-T Ethernet	This cable/category is the minimum requirement for all modern LAN networks.
Cat 6	10Gbps	250MHz	10GBASE-T Ethernet	This cable uses a plastic core to prevent cross-talk between twisted-pair. It also uses a fire-resistant plastic sheath.
Cat 6a	10Gbps	500MHz	10GBASE-T Ethernet	This cable reduces attenuation and cross-talk. This cable also potentially removes the length limit. This is the recommended cable for all modern Ethernet LAN networks.
Cat 7	10Gbps	600MHz	Not drafted yet	This cable sets a base for further development. This cable uses multiple twisted-pairs and shields each pair by its own plastic sheath.

3.2 Scalability[9]:

Three specifications determine the size and scalability of networking media: maximum nodes per segment, maximum segment length, and maximum network length.

3.3 Schematic View:



4. FDDI[10]:

FDDI (Fiber Distributed Data Interface) is a set of ANSI and ISO standards for data transmission on fiber optic lines in a local area network (LAN) that can extend in range up to 200 km (124 miles).FDDI is frequently used on the backbone for a wide area network (WAN).

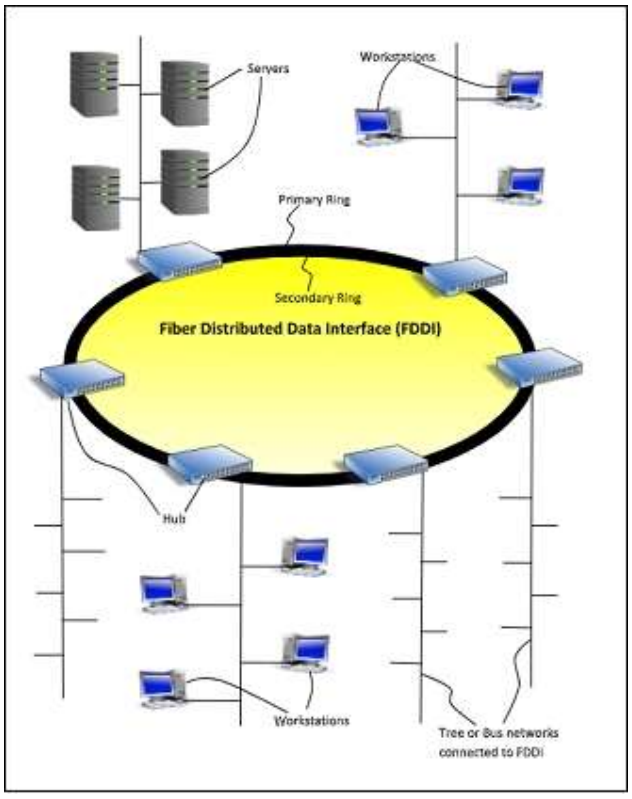
4.1 Specifications[11]:

- Data Rate: 100Mbps.
- Topology: physical ring of trees, logical ring.
- Maximum distance between adjacent stations: 2 km.
- Total max. ring length: 100 km.
- Max. number of attached stations: 1000.

4.2 Scalability[11]:

FDDI are more scalable, as it's simple to install new equipment can over original fiber. Wavelengths can be turned on or off on demand, which allows for the easy provisioning of services and quick scaling for a growing business.

4.3 Schematic View:



4.4**Modulation Scheme[11]:**

There are several coding and compression techniques available for voice. Adaptive Differential Pulse Code Modulation (ADPCM) and Digital Speech Interpolation (DSI) are two of the popular mechanisms for voice compression. DSI is well-suited for packetized voice transmission as it conserves bandwidth during silence intervals in a conversation

5. Coaxial Cable[12]:

When it comes to RF transmission, the coaxial cable becomes a type of transmission line, the go wire takes the form of a centre conductor, and the return wire, known as the outer conductor, consists of an electrical shielding that surrounds the centre conductor.

5.1 Specifications[13]:

Properties of Coaxial Cable Dielectrics(c = speed of light in a vacuum)		
Dielectric Type	Time Delay(ns/ft)	Propagation Velocity
Solid Polyethylene (PE)	1.54	0.659c
Foam Polyethylene (FE)	1.27	0.800c
Foam Polystyrene (FS)	1.12	0.910c
Air Space Polyethylene (ASP)	1.15-1.21	0.840c-0.880c
Solid Teflon (ST)	1.46	0.694c
Air Space Teflon (AST)	1.13-1.20	0.850c-0.900c

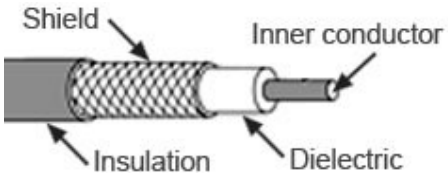
5.2 Scalability[14]:

Three specifications determine the size and scalability of networking media: maximum nodes per segment, maximum segment length, and maximum network length.

Populated segment: is a part of a network that contains end nodes. For example, a switch connecting users in a classroom is part of a populated segment.

Unpopulated segment: also known as a link segment, is a part of the network that does not contain end nodes, but simply connects two networking devices such as routers.

5.3Schematic View[14]:



5.4 Modulation Scheme[14]:

10 Mbit/s Ethernet uses Manchester coding. A binary zero is indicated by a low-to-high transition in the middle of the bit period and a binary one is indicated by a high-to-low transition.

6. USB[15]:

Universal Serial Bus (USB) is a standard interface for connecting peripheral devices to a host computer. The USB system was originally devised by a group of companies including Compaq, Digital Equipment, IBM, Intel, Microsoft, and Northern Telecom to replace the existing mixed connector system with a simpler architecture.

USB was designed to replace the multitude of cables and connectors required to connect peripheral devices to a host computer. The main goal of USB was to make the addition of peripheral devices quick and easy. All USB devices share some key characteristics to make this possible. All USB devices are self-identifying on the bus. All devices are hot-pluggable to allow for true Plug'n'Play capability. Additionally, some devices can draw power from the USB which eliminates the need for extra power adapters.

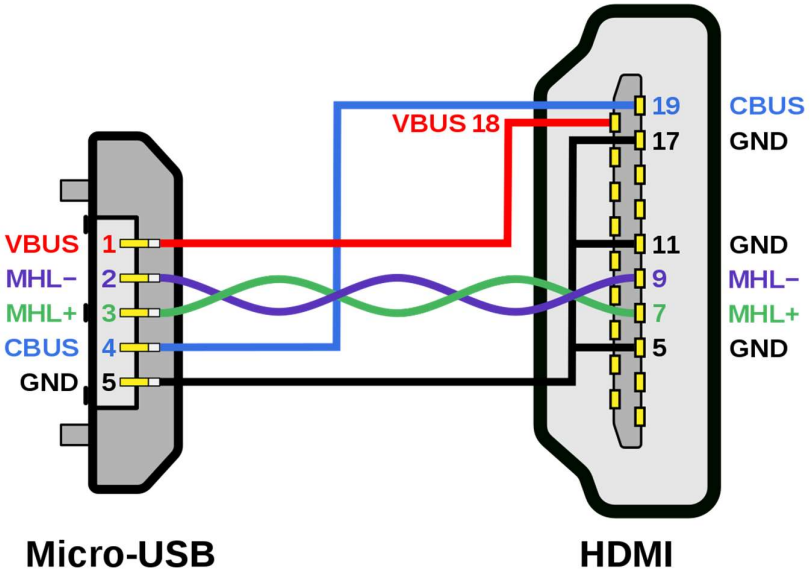
6.1 Specifications[16]:

- Higher data transfer rate (up to 5 Gbps)
- Increased bus power and current draw
- Improved power management
- Full duplex data communications
- Link Training and Status State Machine (LTSSM)
- Interrupt driven, instead of polling
- Streaming interface for more efficient data transfers

6.2 Scalability[16]:

Scalability is a key advantage for achieving efficiency that board-level manufacturers can offer systems designers. With USB as the I/O channel, embedded designers are provided distinct advantages enabling them to maximize efficiencies in their system designs. These advantages are enhanced for the embedded user with StackableUSB, a popular stacking protocol that implements USB, I2C and SPI in a compact, rugged format conducive to industrial control and measurement applications.

6.3 Schematic View:



7. DSL[17]:

DSL is a wired transmission that uses traditional copper telephone lines already installed to homes and businesses. Availability and speed of DSL service may depend on the distance from a home or business to the closest broadband equipped telephone company central office or telephone exchange.

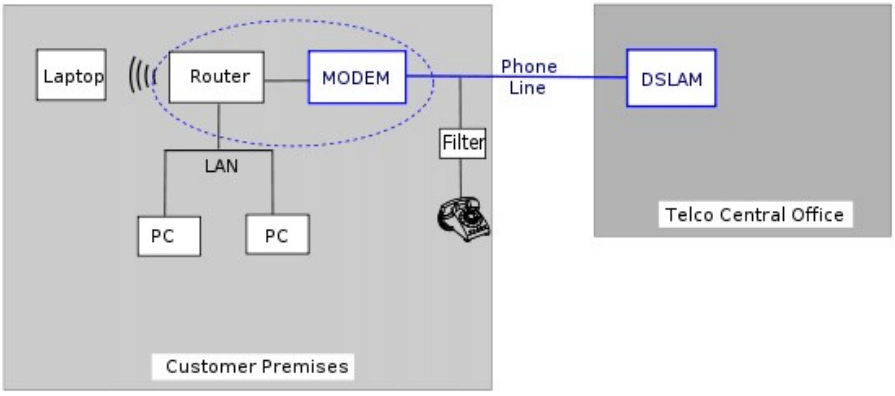
7.1 Specifications[18]:

The bit rate of consumer DSL services typically ranges from 256 kbit/s to over 100 Mbit/s in the direction to the customer (downstream), depending on DSL technology, line conditions, and service level implementation. In general, the maximum range for DSL without a repeater is 5.5 km (18,000 feet). As distance decreases toward the telephone company office, the data rate increases. The typical speed for a DSL connection is 6 Mbps.

7.2 Scalability[19]:

DSL Internet service only works over a limited physical distance and remains unavailable in many areas where the local telephone infrastructure does not support DSL technology. The service is not available everywhere. The connection is faster for receiving data than it is for sending data over the Internet.

7.3 Schematic View:



7.4 Modulation Scheme[19]:

ADSL or G. 992.1 or also G. DMT is the oldest form of modulation. It supports a maximum sync rate of 8Mbps. The next one is ADSL2 also referred to as G.992.3 supports a maximum of 12Mbps sync rate. The newest (if you can even call it new) is ADSL2+ or G.992.5 supports a maximum of 24Mbps sync rate.

Wireless Networks[20]:

A **wireless network** is a computer network that uses wireless data connections between network nodes.

Wireless networking is a method by which homes, telecommunications networks and business installations avoid the costly process of introducing cables into a building, or as a connection between various equipment

locations. admin telecommunications networks are generally implemented and administered using radio communication. This implementation takes place at the physical level (layer) of the OSI model network structure.

Examples of wireless networks include cell phone networks, wireless local area networks (WLANs), wireless sensor networks, satellite communication networks, and terrestrial microwave networks.

1. **Wi-Fi[21]:**

   Wi-Fi is a wireless networking technology that allows devices such as computers (laptops and desktops), mobile devices (smart phones and wearables), and other equipment (printers and video cameras) to interface with the Internet. It allows these devices--and many more--to exchange information with one another, creating a network.

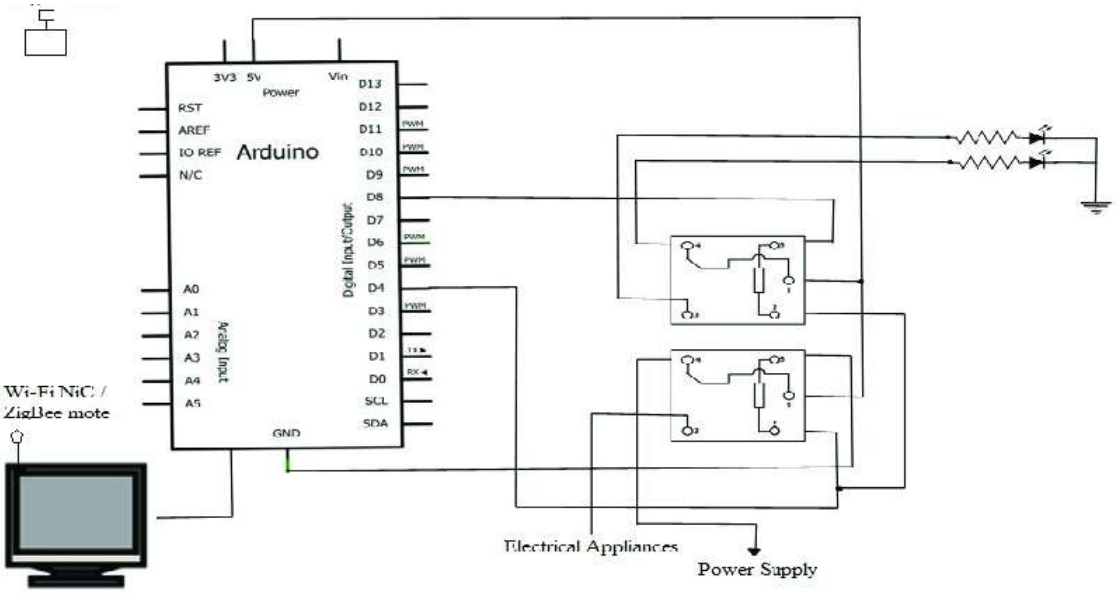
   1.1 Specifications[22]:

Generation/IEEE Standard	Maximum Linkrate	Frequency
Wi-Fi 5 (802.11ac)	433–6933 Mbit/s	5 **GHz**
Wi-Fi 4 (802.11n)	72–600 Mbit/s	2.4/5 **GHz**
Wi-Fi 3 (802.11g)	3–54 Mbit/s	2.4 **GHz**
Wi-Fi 2 (802.11a)	1.5 to 54 Mbit/s	5 **GHz**

   1.2 Scalability[23]:

   Speed and distance. Speed and distance can be important factors in **scalability** of a **WLAN**. ... 802.11a and 802.11g provide more **scalability** in this regard than 802.11b, and with 802.11a you can combine channels to get even higher throughput. Distance range can also be a factor in the **scalability** of your **WLAN**.

   1.3 Schematic View:



1.4 Modulation Scheme[23]:

Wi-Fi systems use two primary radio transmission techniques. The bit stream is processed with a special coding and then **modulated** using Quadrature Phase Shift Keying (QPSK). ... 802.11a and g (<=54 Mbps) − The 802.11a and g systems use 64-channel orthogonal frequency division multiplexing (OFDM).

2. Zigbee[24]:

Zigbee is a wireless technology developed as an open global standard to address the unique needs of low-cost, low-power wireless IoT networks. The Zigbee standard operates on the IEEE 802.15.

2.1 Specifications[25]:

Zigbee Technical Specifications

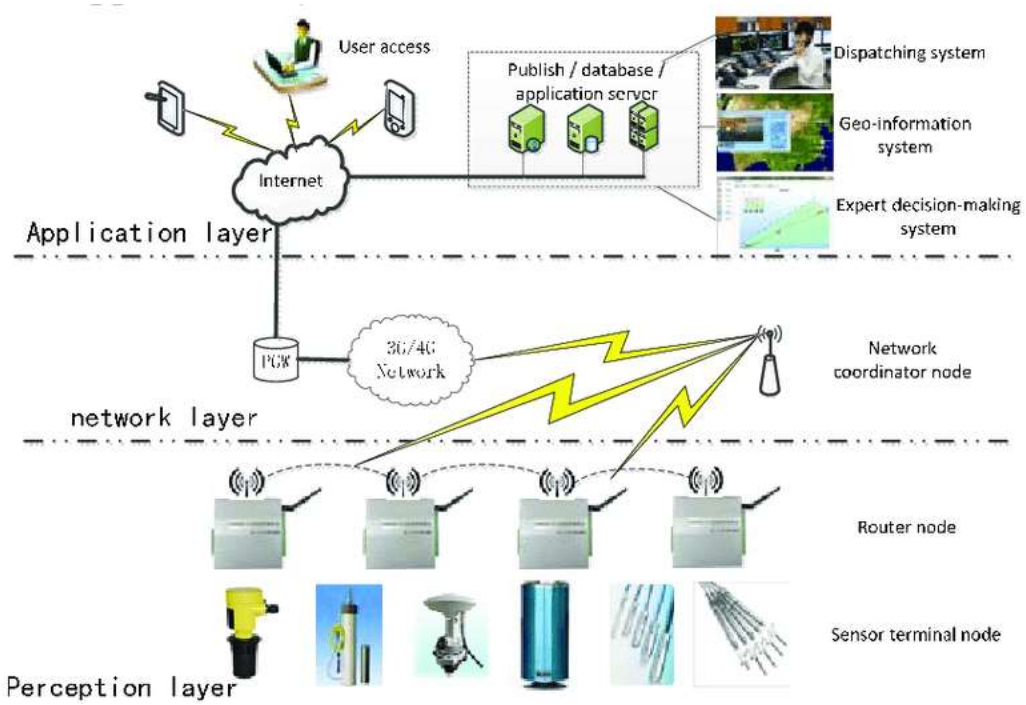
Solution	Description
Network Protocol	Zigbee PRO 2015 (or newer)
Network Topology	Self-Forming, Self-Healing MESH
Network Device Types	Coordinator (routing capable), Router, End Device, Zigbee Green Power Device
Network Size (theoretical # of nodes)	Up to 65,000
Radio Technology	IEEE 802.15.4-2011
Frequency Band / Channels	2.4 GHz (ISM band) 16-channels (2 MHz wide)
Data Rate	250 Kbits/sec
Security Models	Centralized (with Install Codes support) Distributed
Encryption Support	AES-128 at Network Layer AES-128 available at Application Layer
Communication Range (Average)	Up to 300+ meters (line of sight) Up to 75-100 meter indoor
Low Power Support	Sleeping End Devices Zigbee Green Power Devices (energy harvesting)
Legacy Profile Support	Zigbee 3 devices can join legacy Zigbee profile networks. Legacy devices may join Zigbee 3 networks (based on network's security policy)
Logical device support	Each physical device may support up to 240 end-points (logical devices)

2.2 Scalability[26]:

The Zigbee network specification states that networks can theoretically scale to thousands of nodes per network. However,

realistically, and in practice, Zigbee networks can scale to hundreds of nodes in a single network. Our point-to-point/Bluetooth option is limited to two nodes and Wi-Fi to 15 devices per access point.

2.3 Schematic View:



2.4 Modulation Scheme[27]:

Zigbee uses the offset quadrature phase-shift-keyed (OQPSK) modulation stream. This scheme is a derivation of traditional QPSK and is used because it requires less power than similar schemes, while achieving the same or better throughput. OQPSK uses a maximum phase transition of 90 degrees from one symbol to the next. This prevents symbol overshoot and requires slightly less transmission power than the traditional QPSK modulations scheme. This design decision, combined with the use of a 5-MHz channel bandwidth enables devices to achieve a data rate of up to 250 kb/sec in a reasonably power-efficient manner.

3. **LTE[28]:**

In telecommunications, Long-Term Evolution (LTE) is a standard for wireless broadband communication for mobile devices and data terminals, based on the GSM/EDGE and UMTS/HSPA technologies. It increases the capacity and speed using a different radio interface together with core network improvements. LTE is the upgrade path for carriers with both

GSM/UMTS networks and CDMA2000 networks. The different LTE frequencies and bands used in different countries mean that only multi-band phones are able to use LTE in all countries where it is supported. LTE is sometimes known as 3.95G and has been marketed both as "4G LTE" and as "Advanced 4G".

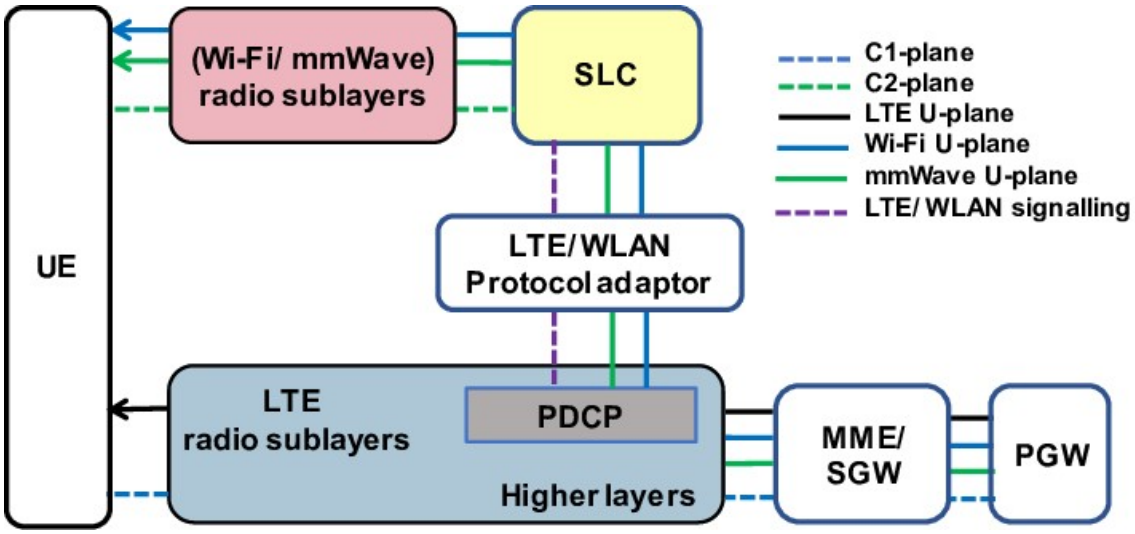
3.1 Specifications[28]:

The LTE specification provides downlink peak rates of 300 Mbit/s, uplink peak rates of 75 Mbit/s and QoS provisions permitting a transfer latency of less than 5 ms in the radio access network. LTE has the ability to manage fast-moving mobiles and supports multi-cast and broadcast streams.

3.2 Scalability[29]:

Long Term Evolution (LTE) system employs Orthogonal Frequency Division Multiple Access (OFDMA) in downlink in order to support network deployment using various system bandwidth configurations i.e., 1.4MHz, 3MHZ, 5MHz, 10MHz, 15MHz and 20MHz. The bandwidth scalability enables operator to access multiple channels to achieve higher peak data rates. Also, the bandwidth scalability allows operators to deploy LTE network with the existing spectrum or newly licensed band. Therefore the study on performance of LTE system with different bandwidth configuration becomes vital. Hence in this paper, an attempt has been made to study and compare the performance of LTE system with different spectrum configuration i.e., 1.4MHz, 3MHz, 5MHz, 10MHz, 15MHz and 20MHz for Constant Bit Rate (CBR) traffic scenario in the downlink.

3.3 Schematic View:



3.4 Modulation Scheme[29]:

Each symbol represents bits depending on the modulation technique, Each data point represents a different bit pattern. LTE devices use QPSK, 16QAM and 64QAM to modulate data and control information. The eNodeB supports all of these modulation techniques for the Down Link direction. However, 64QAM is optional in the Uplink direction. A modulation technique is selected based on the measured Signal to Noise Ratio (SNR). Subscribers located away from the eNodeB must use more robust modulation schemes (lower throughput), or they will experience unacceptable data loss rates. In addition, subscribers close to a sector boundary may experience inter-sector interference.

4. NFC[30]:

Near Field Communication (NFC) is a contact-less communication technology based on a radio frequency (RF) field using a base frequency of 13.56 MHz. NFC technology is perfectly designed to exchange data between two devices through a simple touch gesture.

4.1 Specifications[31]:

NFC Forum Devices are able to communicate with:

- Readers and cards compliant to the ISO/IEC 14443 Type A standard
- Readers and cards compliant to the ISO/IEC 14443 Type B standard
- Cards compliant to the ISO/IEC 15693 standard
- Devices compliant to the ISO/IEC 18092 standard
- Readers and cards compliant to the JIS-X 6319-4 standard
- NFC Forum Tags
- Other NFC Forum Devices

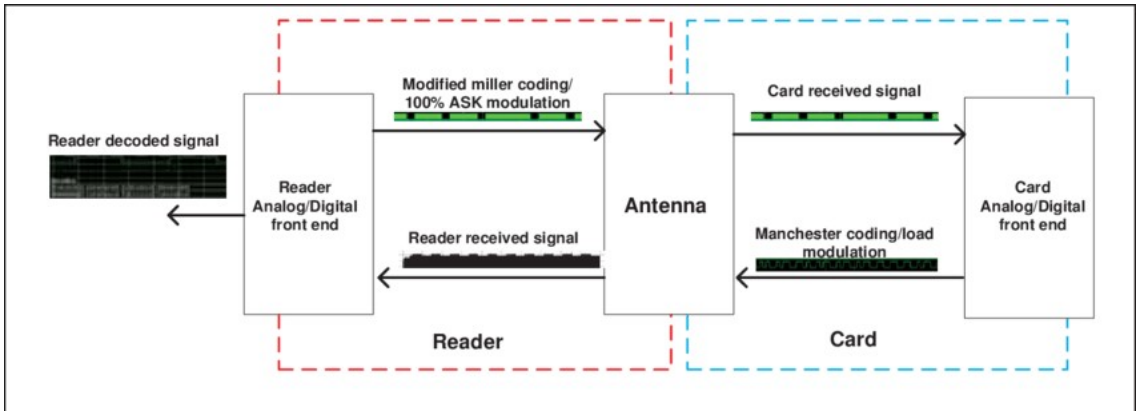
Depending on the communication protocol used and the capability of the remote device, a communication speed of up to 424 Kbit/s is supported by NFC Forum Devices.

4.2 Scalability[31]:

NFC is the most scalable and secure of all mobile payment and wireless data transfer technologies and will represent a paradigm shift in how we live – making everyday activities easier and more convenient. Using an NFC enabled smartphone will make accessing new media and content not just truly interactive but much more

intuitive; make it easier to pay for things; easier to discover and share information and much easier to use transport – in this one area alone NFC could have a major impact on our lives with travellers using their phones as fare cards or to store long-distance tickets without fear of losing them.

4.3 Schematic View:



4.4 Modulation Scheme[31]:

NFC employs two different coding systems on the RF signal to transfer data. In most cases a level of 10% modulation is used, with a Manchester coding format. However for an active device transmitting data at 106 kbps, a modified Miller coding scheme is used with 100% modulation. In all other cases Manchester coding is used with a modulation ratio of 10%.

5. Bluetooth[32]:

The two current technologies for wireless personal area networks are InfraRed (IR) and Bluetooth (IEEE 802.15). These will allow the connectivity of personal devices within an area of about 30 feet. However, IR requires a direct line of site and the range is less.

5.1 Specifications[32]:

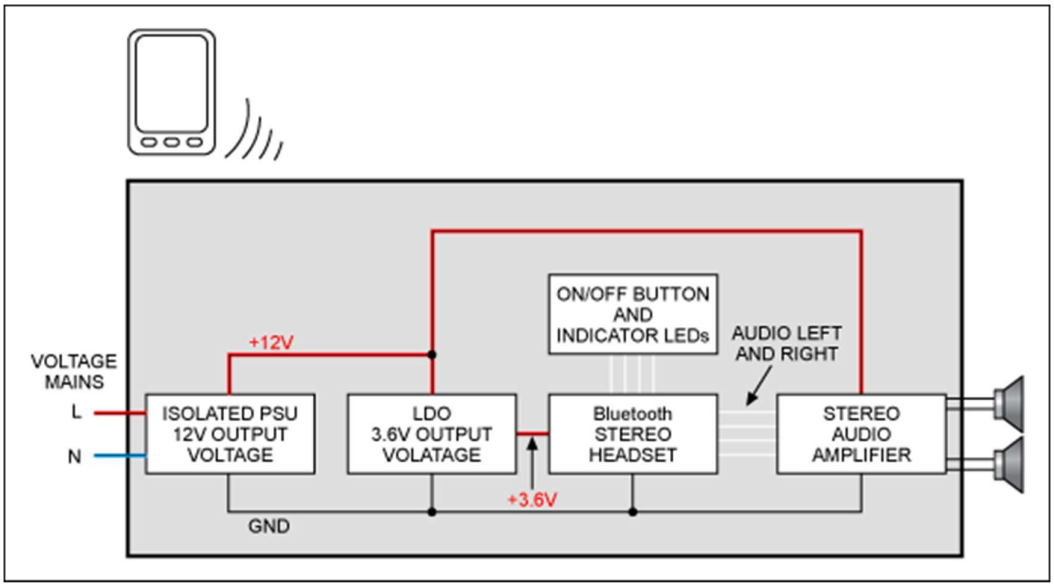
Bluetooth operates at frequencies between 2.402 and 2.480 GHz, or 2.400 and 2.4835 GHz including guard bands 2 MHz wide at the bottom end and 3.5 MHz wide at the top. This is in the globally unlicensed (but not unregulated) industrial, scientific and medical (ISM) 2.4 GHz short-range radio frequency band.

5.2 Scalability[33]:

Bluetooth mesh networks support reliable, scalable, secure solutions for a wide range of commercial and industrial IoT applications for control, monitoring, and automation where tens, hundreds, or

thousands of devices need to reliably and securely communicate with one another.

5.3 Schematic View:



5.4 Modulation Scheme[33]:

Bluetooth uses Frequency Hopping Spread Spectrum technique which is used in spread spectrum signal transmission. During radio transmission, frequencies are switched repeatedly, to help reducing unlawful access to cross paths which causes interruptions. FHSS makes Bluetooth communication more robust and secure. The speed of interferences from other devices will be reduced, though it will not cause the transmission to stop. Adaptive modulation and coding methods, OFDM, GMSK, QAM, CDMA, DMT and similar methods are utilized in the areas of wireless, cellular and satellite communication systems. These modulations are used in wireless, cellular, wired line and satellite communication systems.

6. Li-Fi[34]:

Li-Fi (short for light fidelity) is wireless communication technology which utilizes light to transmit data and position between devices.

6.1 Specifications[35]:

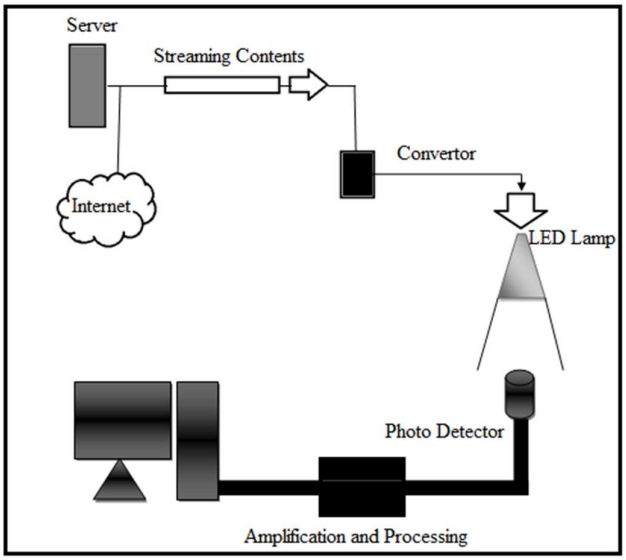
Type: Current Steering Segmented
DACs per Chip: 4
Resolution: 8 bits
Current Drive: Adjustable, 30mA – 255mA
Sampling rate: Up to 500 MS/s
Nyquist rate: Up to 250MHz

Clock+ Data I/F: 500MHz LVDS
Configuration I/F: 1MHz serial interface
Chip Area: ~ 30 Sq. mm
Additional Features: GANG/MIMO operation Adjustable offset current (0 – 120mA)

6.2 Scalability[35]:

LiFi offers scalable capabilities for up to 15 users within the coverage beam of one light point.

6.3 Schematic View:



6.4 Modulation Scheme[35]:

SINGLE-CARRIER MODULATION Widely used single-carrier modulation (SCM) schemes for LiFi include on-off keying (OOK), pulse position modulation (PPM) and pulse amplitude modulation (PAM), which have been studied in wireless infrared (IR) communication systems.

7. 4G[36]:

4G is a loose term for the fourth generation of cellular communications, offering speeds that are about 10 times faster than they are on current third-generation, or 3G, networks. Its higher data speeds could make smartphones much more comparable to PCs, giving them better multimedia and gaming capabilities.

7.1 Specifications[37]:

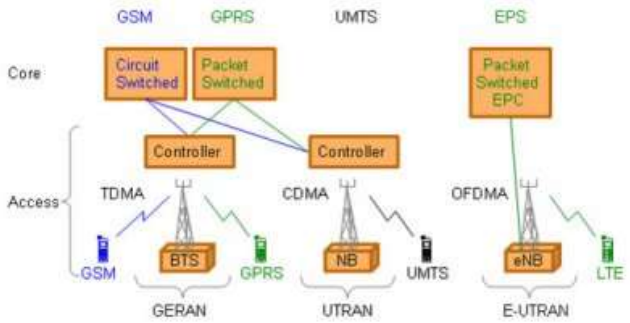
Frequency Band: 2-8 GHz
Bandwidth: 5-20 MHz
Data rate: Upto 20Mbps or more

Access: Multi-carrier - CDMA or OFDM(TDMA)
FEC: Concatenated codes
Switching: Packet
Mobile top speeds: 200kmph

7.2 Scalability[38]:

Scalability down to Pico cells and locations up to 10^10 users globally.

7.3 Schematic View:



7.4 Modulation Scheme[39]:

At present 4G uses QAM with OFDM as modulation and OFDMA as access scheme.

References:

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